



# On the Luminosity Lifetimes, Emittance Growth Rates.... Intra-Beam Scattering at 980 GeV, for Protons.



## Relevant Machine/Beam Parameters

Lorentz boost  $\gamma = 1045$ . (980 GeV)

Average  $\beta_{x,y}$  function  $\sim 71.5$  m.

Average Dispersion  $D_x \sim 2.84$  m.

Transverse Coupling  $\kappa \sim 0.3$  ?

Revolution Frequency  $f = 47713$  Hz

## Proton Beam

# of protons/per bunch  $\sim 1.70$  to  $2.30 \times 10^{11}$

Typical Bunch Length  $\sigma_\tau = 2.1$  ns.

$\delta P/P \sim 1.4 \times 10^{-4}$

Transverse Emittance ( $x,y$ )  $\sim 25$  pi mm mRad (95%)

(From Flying Wire)

Effective Transverse Emittance  $\sim 16$  to  $19$  pi mm mRad

□ □ ( From Luminosity measurements)

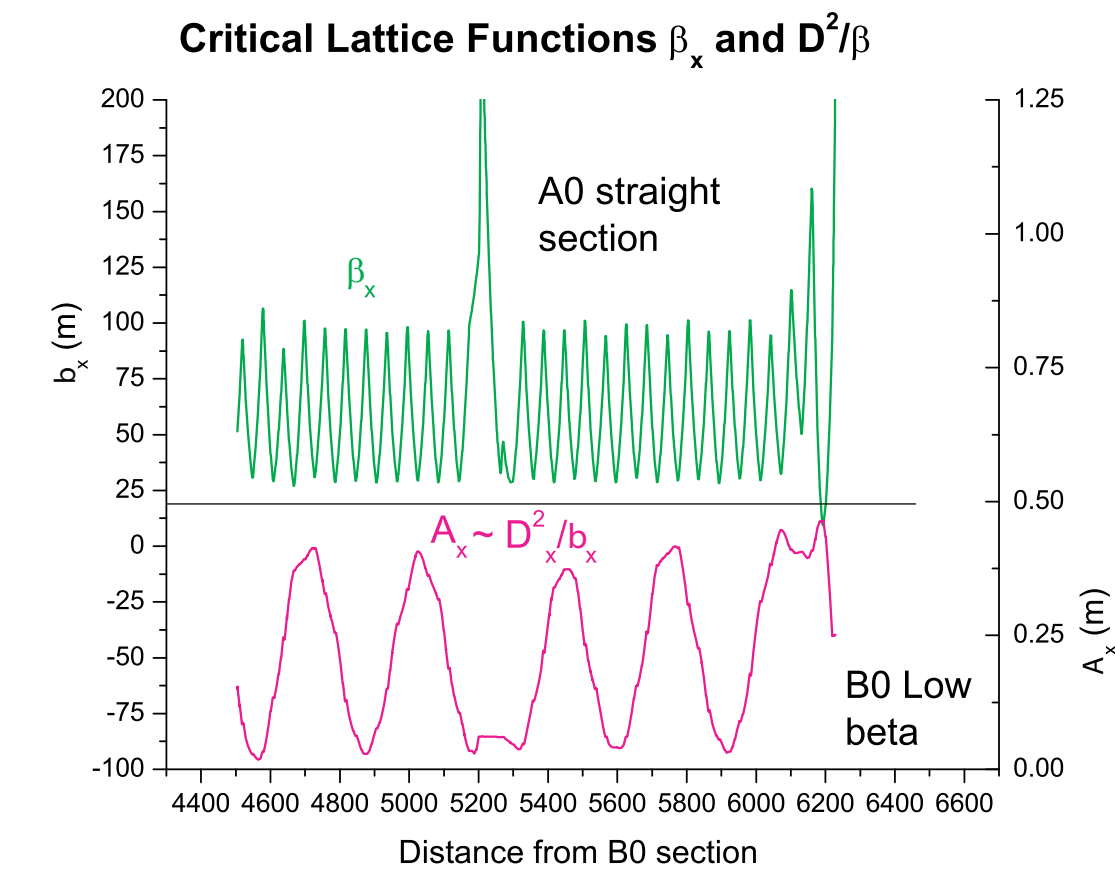
$$\begin{bmatrix} d\epsilon_x/dt \\ d\epsilon_y/dt \end{bmatrix} \approx \frac{L_c N_0 r_0^2 A_{av}}{4 \sqrt{2} \gamma^3 \sigma_\tau \sigma_x \sigma_y \sqrt{\theta_x^2 + \theta_y^2}} \begin{bmatrix} 1 - \kappa \\ \kappa \end{bmatrix}$$

where

$$A_x = \frac{D_x^2 + (dD_x/ds \beta_x + \alpha_x D_x)^2}{\beta_x}$$

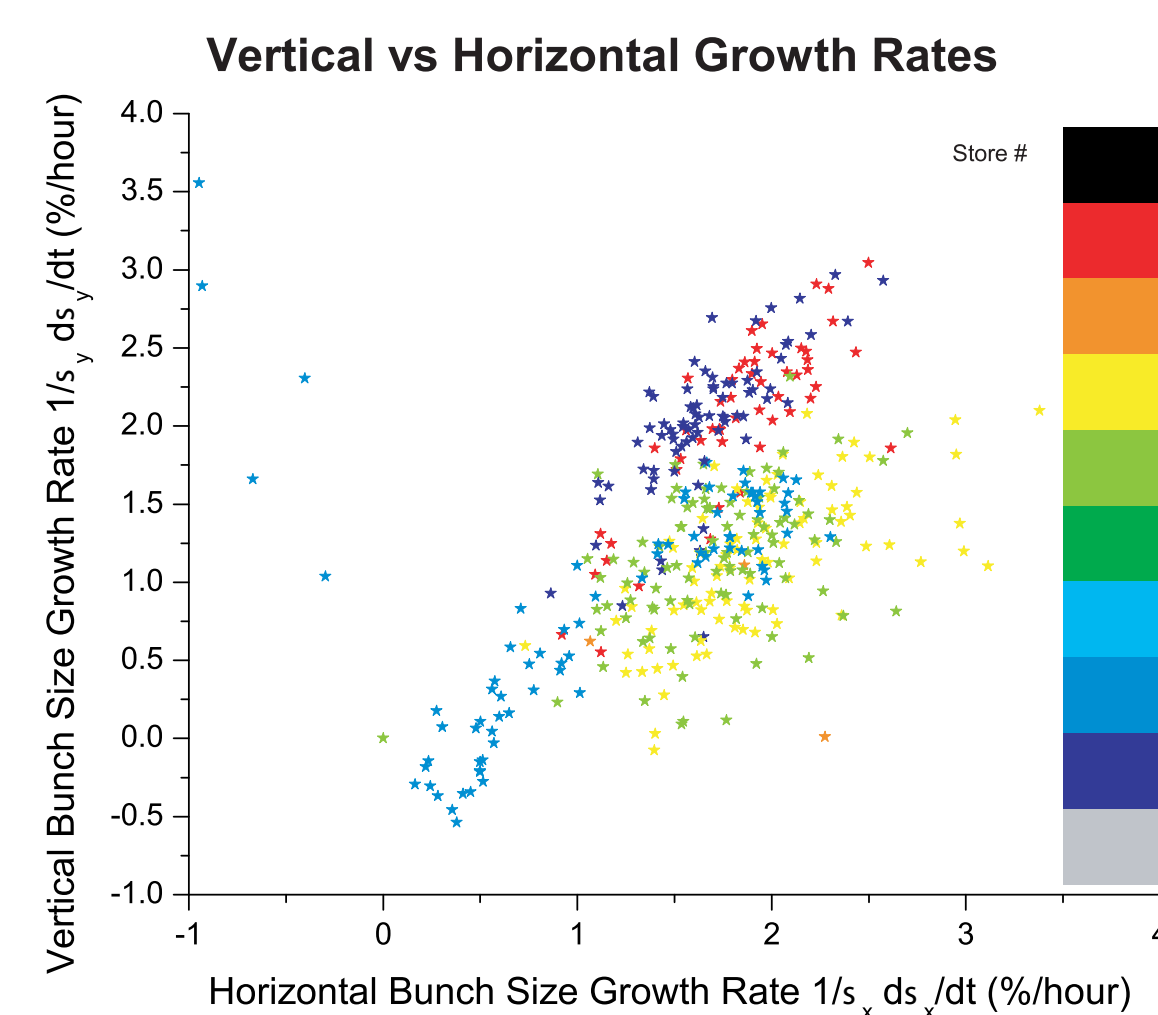
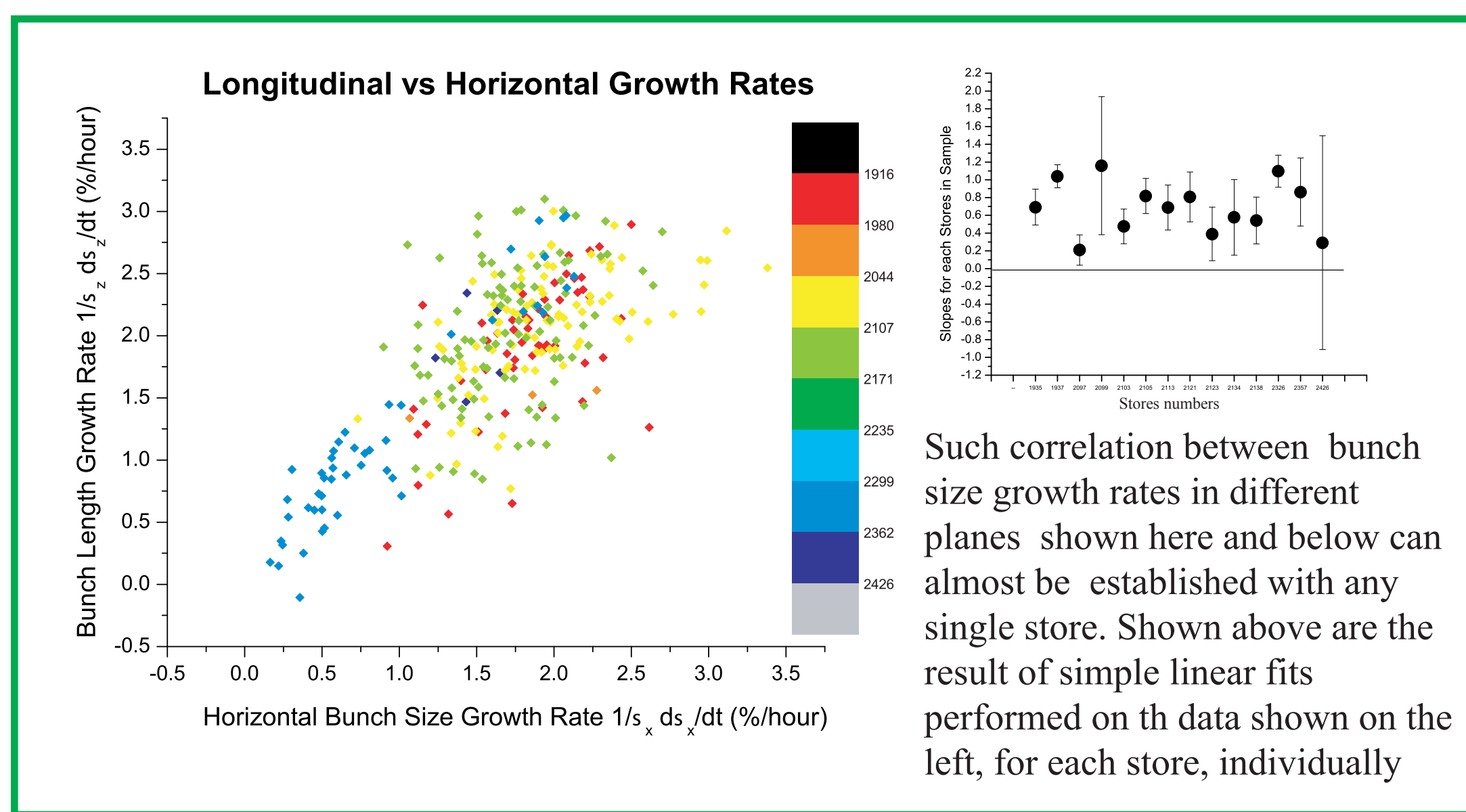
Likewise, longitudinally,

$$r_{\epsilon,z} = \frac{d\epsilon_s}{\epsilon_s dt} = \frac{L_c N_0 r_0^2 \Gamma_s^2}{4 \sqrt{2} \gamma^3 \sigma_\tau \sigma_x \sigma_y \sqrt{\theta_x^2 + \theta_y^2}}$$



## Observations: Correlations between Longitudinal and Transverse, at Synchrotron Light Monitor.

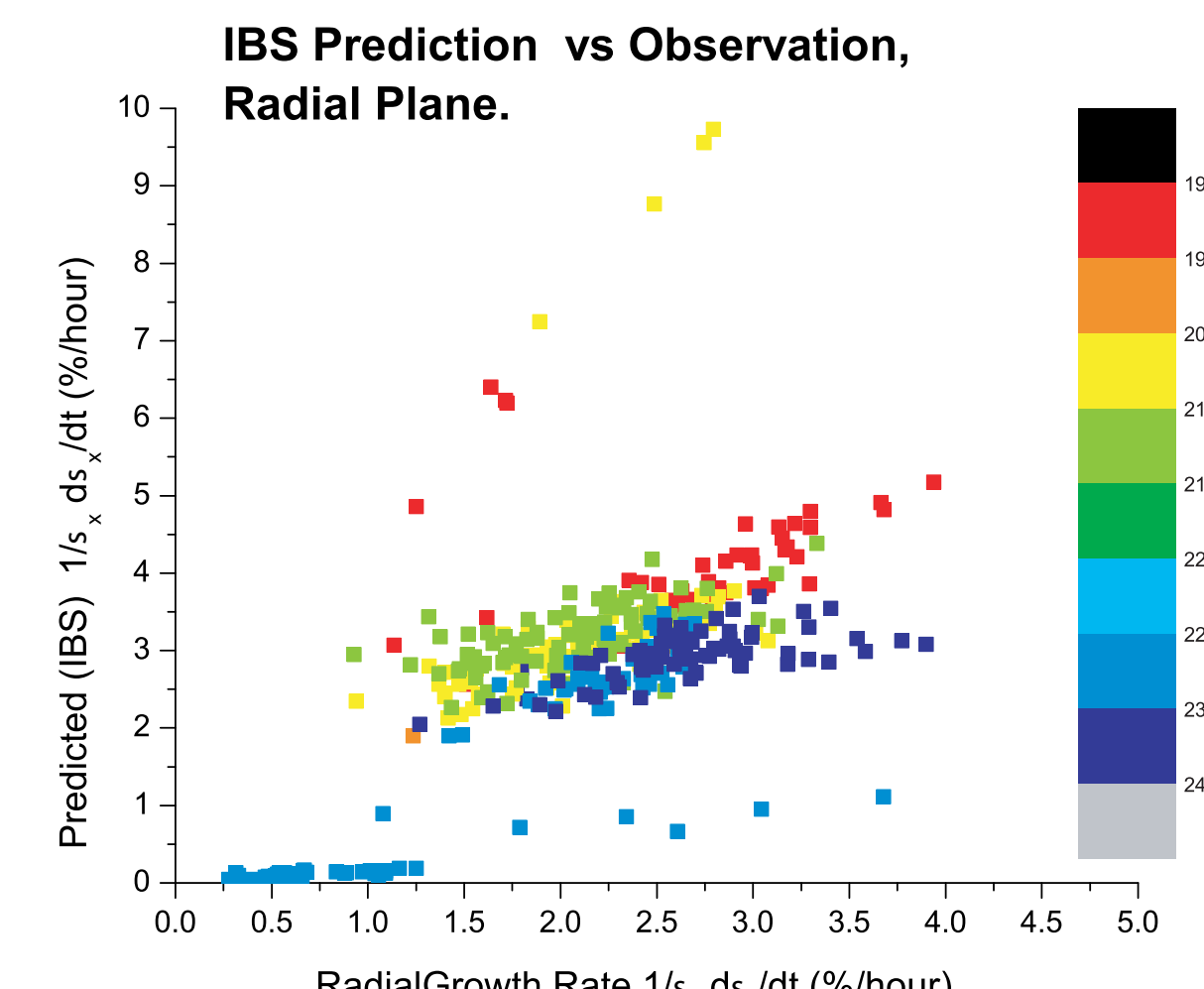
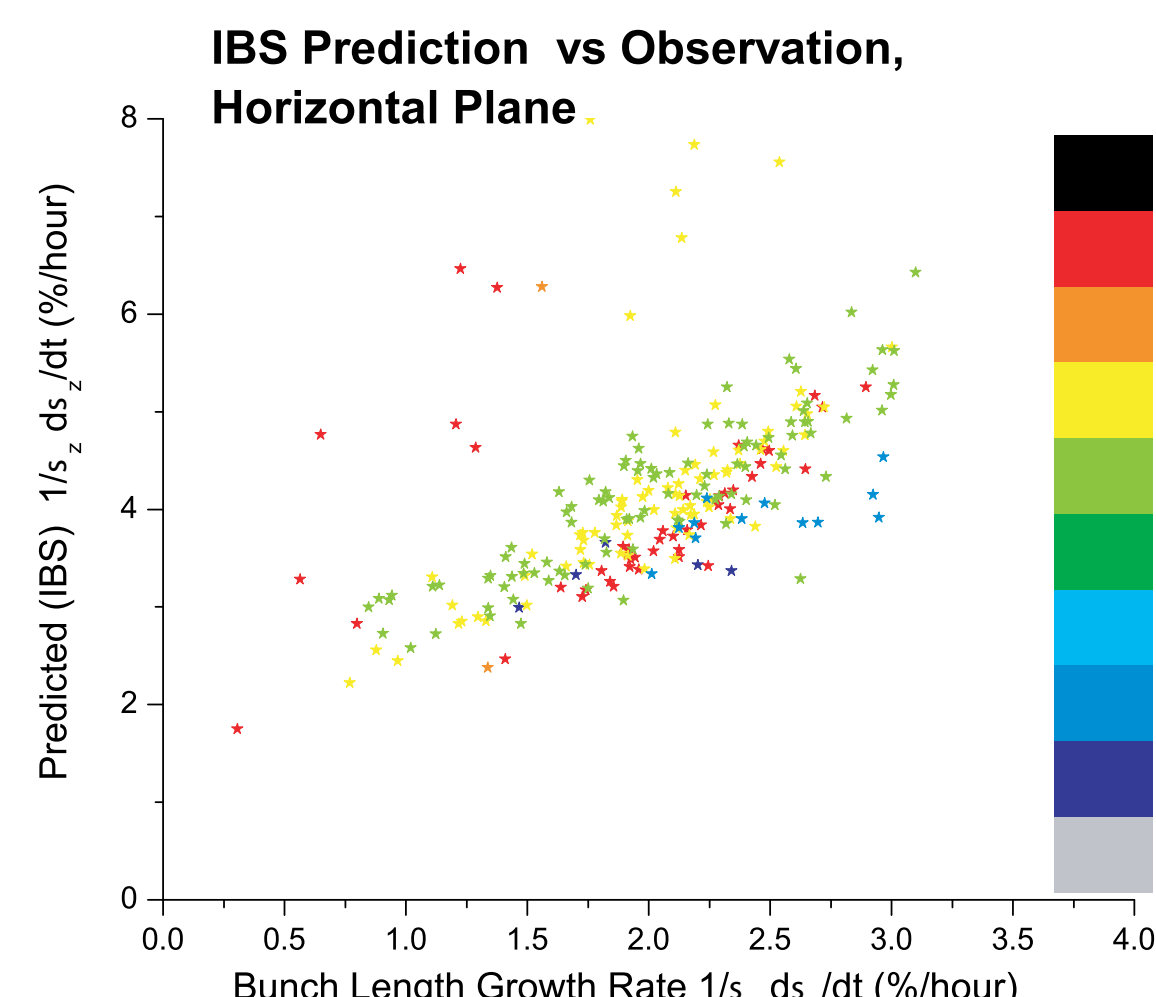
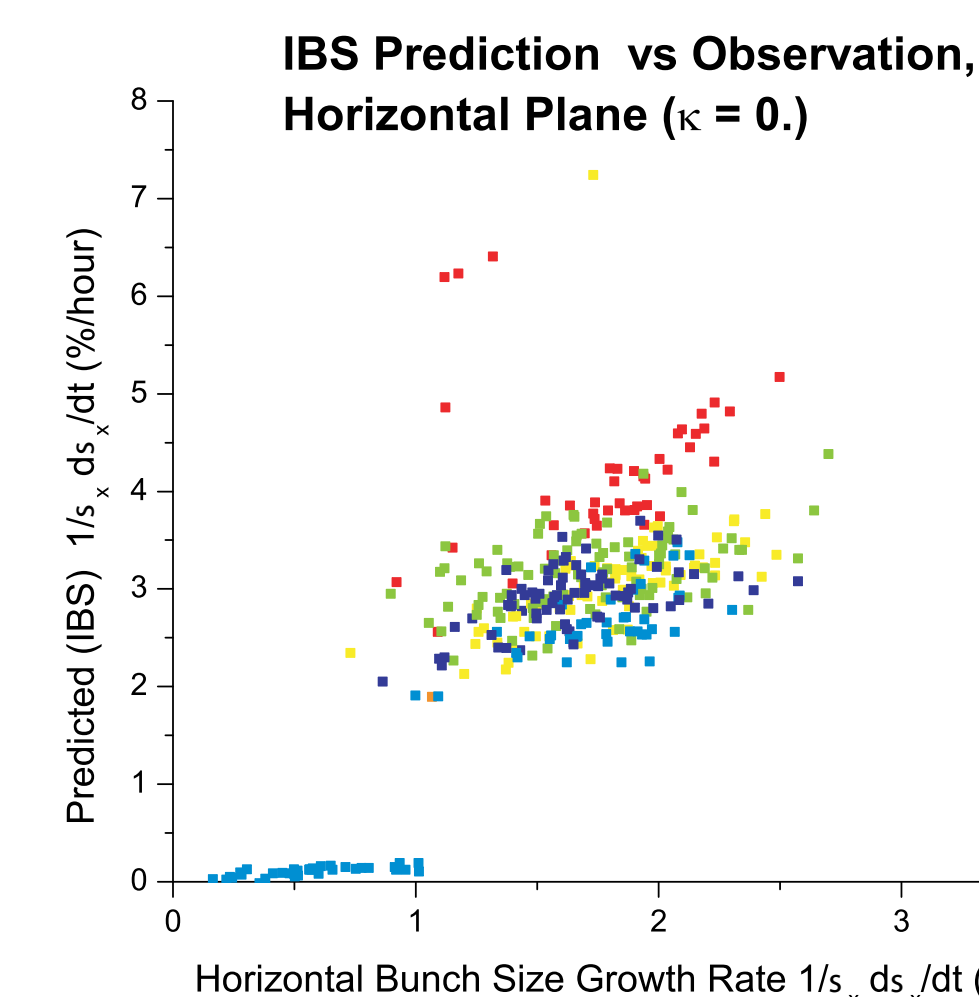
Data Selection : Proton Lifetime due to non HEP collisions (beam losses due to unknown causes)  $\sim 70$  hours  
Synchrotron Light bunch sizes (rms) must have "physically" valid values, between 300 and 700 microns, corresponding to reasonable emittances. Growth rate fits performed on the raw data reject points that are at  $\sim 5 \sigma$  off the average curve.



While the relationship between the horizontal and longitudinal emittance growth rates was anticipated, the correlation between the growth rates in the horizontal and vertical planes is troublesome. We have other indications coming from direct lattice measurement that the Tevatron has a rather strong betatron coupling factor. Thus, bunch are expanding in all 3 planes at the rate of  $\sim 2$  to  $3$  percent per hour, at the beginning of the store. These rate slowly go down as the bunch becomes more diffuse.

## Direct Comparison between Intra-Beam Scattering predictions and the measured growth rates

While the measured growth rates  $1/\sigma d\sigma/dt$  are independent of an overall scale factor in the bunch size, the predicted IBS rate do depend critically on the absolute value of these bunch size and thereby the emittances. Here, we use the Flying Wires, the Synchrotron Light Monitor and the Sample Bunch Display to compute the IBS growth rates. We are therefore sensitive to absolute emittance scale factor in this analysis.



**Conclusion:** Despite a few obviously wrong emittance measurements, there is a clear correlation between predicted and observed growth rates. The uncertainties are relatively large ( $\sim 50\%$ ). Yet, this work gives us confidence in the model predicting the luminosity lifetime at higher luminosity, which is expected to be  $\sim 6$  hours.